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## REGENERATION OF THE LEG OF AMPHIUMA MEANS.

T. H. MORGAN.

My object in studying the regeneration of the limbs of *Amphiuma means* was to discover whether the limbs, which appear to be of so little use to the animal as organs of locomotion, have the power to regenerate as have the limbs of other urodele amphibia.

The first amphiuma that I obtained (in 1900) was a large individual, and after several months had begun to regenerate, but died as the result of an accident before regeneration had gone very far.<sup>1</sup> The next individual that I was able to procure was also large, but escaped before regeneration had gone any farther than in the last case. Two smaller individuals have been kept for more than a year (from March 21, 1901, to May 3, 1902). The following account applies to them. Each had a fore-leg and hind-leg of opposite sides cut off through the upper portion of the leg. In the course of several weeks a knob of new tissue appeared which continued to elongate for several months, when further growth seemed to have ceased. To make certain of this, the animals were kept for six months longer, but no further change occurred. The new part was shorter than the part removed, and appeared to be a single rod, tapering at the end, without any external signs of toes.

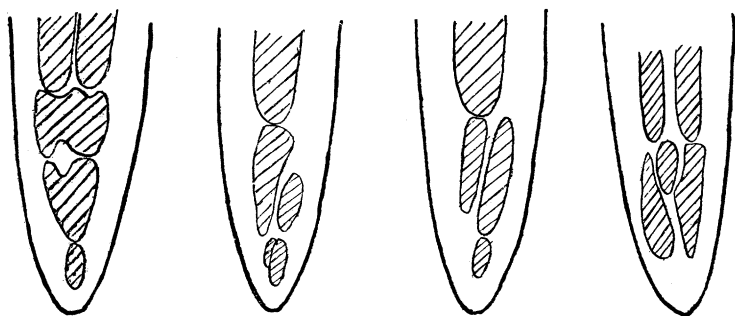
The normal fore- and hind-foot of the amphiumas that I used had each three toes. Cope<sup>2</sup> gives a figure of the skeleton of amphiuma showing a cartilaginous carpus of four or five pieces, and three ossified metacarpals with ossified phalanges. In the hind-foot there are three cartilaginous tarsalia, three ossified metatarsals and three phalanges.

After the legs had regenerated they were cut off, imbedded in paraffine, and cut into sections. These showed in three of the four cases that the two bones of the middle part of the limb have

<sup>1</sup> This is the case referred to in Towle's paper. BIOLOGICAL BULLETIN, II., 1901.

<sup>2</sup> Cope, "The Batrachia of North America," Bull. U. S. Nat. Mus. No. 34.

developed. The condition of the carpus and tarsus appears to be different in each of the four cases, Figs. 1-4. The rough reconstructions shown in these figures were made from sections. The figures are not very accurate, but serve to show the number of bones and their relation to each other. The relative sizes of the bones is less exact. It will be seen from the figures that the regeneration has lead neither to the formation of a uniserial row of skeletal elements, nor is it clear in all cases whether more than a single toe is represented. It seems probable that the



terminal middle phalanx represents a toe, but whether any of the other cartilages represent other suppressed toes can not be stated.

In these four cases the legs had been cut off through the humerus, or the femur. It occurred to me that if the limb were cut off through the fore-arm or the fore-leg the result might possibly be different, since two bones are present at the cut surface. Therefore on May 3, 1902, when the two regenerated legs were removed for study, the remaining two legs were cut off through the fore-leg and fore-arm.

The two amphiuma were kept alive for nearly another year; until March 30, 1903. They were occasionally fed on earthworms. The limbs that had been cut off through the fore-arm and fore-leg regenerated, but again produced only a single pointed, or in one case a somewhat flattened, new part. Serial sections show that, besides completing the ends of the two bones at the exposed surface, there have been produced a number of more distal cartilages. The arrangement of these pieces is irregular, and different in each case, as also occurred when the leg was

cut off through the upper portion. In other words, no better regeneration took place here than in the former instances.

It is also of interest to notice that the other two legs that had been cut off (close to the body) for examination had not regenerated. The skin grew over the cut surface, and in several cases the muscles of the body wall seemed to have grown over the short piece of the humerus or femur that had been left. At most, a short protrusion indicated the position of the limb.

How shall we interpret this result. Those who hold that the power to regenerate a part is commensurate with the value of the part to the animal, if it is a part liable to injury, will welcome this experiment as in harmony with their interpretation. On the other hand, as I have tried to show elsewhere, the evidence is so strong against this point of view that I think we shall not go wrong if in this case we deny that the result has any such meaning.

In fact, in other adult amphibia, in the frogs for instance, in which the limbs are of some importance to the animal they cannot be regenerated, although in the tadpole stage in which the limbs are of no importance, and, in the case of the fore-limb at least, not liable to injury, the power of regeneration is present. Moreover even in the urodeles the power of regeneration is unequally developed in forms that use their legs for purposes of locomotion. It is said that *Triton marmoratus* shows only a slight power to regenerate its legs. In other cases, as I have observed in *Necturus*, the time required to regenerate a leg is so long that were the presence of the leg essential to the existence of the individual it would succumb before the regeneration could take place.

These considerations make it clear, in my opinion, that the lack of complete power to regenerate in amphiuma can not be interpreted as having any connection with the unimportance of the legs to the animal. It should not be overlooked that it is not that the leg does not regenerate at all; in fact it regenerates quite well, but that the new part is different from the old. It is at least conceivable that some simple physical or physiological factor may interfere with the formation of the complete toes, such, for instance, as the thickness of the skin in relation to the size of the limb.

If it could be shown that the leg of amphiuma is a degenerate structure it might appear that there is some connection between the degeneracy of the part and its lack of power to regenerate, but it is far from being established that any such general relation really exists. In fact, in the male hermit crab I found that the very small and *apparently* rudimentary abdominal appendages have the power to regenerate. It would be interesting, nevertheless, to examine this point further in cases where the degeneration and uselessness of an organ are more certainly established, as in the case, for example, of the appendix of man, which does not appear to have the power to regenerate after removal.

WOODS HOLL, MASS., June 22, 1903.